

STABILITY OF HYDRATED SALTS AND GOETHITE WITHIN THE DESICCATED UPPER LAYER OF THE MARTIAN REGOLITH

Zolotov, M. Yu.^{1,2}, E.V. Zabalueva¹, and R.O. Kuzmin¹, ¹, Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow 117975, Russia; ², Planetary Chemistry Laboratory, Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130 (zolotov@levee.wustl.edu)

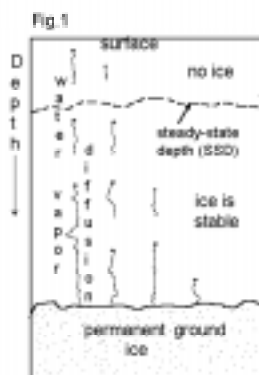
Summary Stability of hydrous sulfates and chlorides of Ca, Mg, and Fe as well as goethite in the uppermost (<50-100 meters) ice-free desiccated regolith layer on Mars has been theoretically analyzed by chemical thermodynamic methods. Latitudinal and depth zonality of hydrate stability have been predicted based on those evaluations. The results shows that ice-free desiccated regolith could contain relatively high contents of bound water even in the equatorial region.

Introduction The modern structure of the upper layers of the Martian cryolithosphere in the equatorial and middle latitudes was formed as a result of ground-ice sublimation and diffusion loss of water to the atmosphere [1-4]. Near the surface ground ice is unstable at those latitudes, and might exist only at some depth, which depends on the latitude. Studies, based on morphology of rampart craters (e.g. [5]) showed, that in the equatorial region a high content of ground ice could exist below 300-400 m. Above that depth ice content should reduced toward the surface. Mellon et al. [6] modeled the ground ice sublimation and water vapor diffusion to the surface. They found, that above some depth (steady-state depth, SSD) ice is unstable (desiccated regolith layer), while below the SSD ice might be stable, while it is a zone of permanent ice-vapor redistribution caused by water vapor diffusion to the surface. The SSD value is dependent on regolith physical

above the roof of the permanent ground-ice-bearing regolith (Fig. 1).

Model We modeled deep (>300 m) ground ice sublimation, water vapor diffusion to the surface, and vapor-ice redistribution below the SSD as a function of depth, latitude, and physical properties of regolith. Mean annual values for surface temperatures (calculated by [8]) and atmospheric water content were used as input parameters [9]. Seasonal T-P_{H₂O} changes within the uppermost 5 meters of the regolith were neglected. SSD values were calculated from temperature corresponding to SSD taking into account a geothermal gradient of 0.207 (K m⁻¹) by the following implicit equation: $(C_{(T)} - C_{(a)})/(T - T_s) = dC/dT$, where C_(T), water vapor equilibrium content for vapor-ice equilibrium; C_(a), atmospheric vapor content; T_s, surface temperature. For a fine grain regolith and for average regolith models we used the thermal conductivity values of $3.38 \cdot 10^{-4}$ and $6.4 \cdot 10^{-4}$ (cal·cm⁻¹·s⁻¹·K⁻¹) respectively. Those values corresponds to thermal inertia values of $3 \cdot 10^{-3}$ and $6 \cdot 10^{-3}$ (cal·cm⁻²·s^{-0.5}·K⁻¹). The adopted geothermal flux was $7 \cdot 10^{-7}$ (cal·cm⁻²·s⁻¹) [10]. Below the SSD that model provides P_{H₂O} values according to vapor-ice equilibrium and a linear P_{H₂O} distribution above the SSD up to the 5 m depth. Calculated temperatures, P_{H₂O} and SSD values within desiccated regolith were used for evaluations of stability of hydrates.

Results The calculated SSD values depend on latitude and the model adopted for regolith properties. For the fine-grain regolith (Fig. 2) the SSD values changes from about 40 meters for equatorial regions to 0 m around 45° latitude, where ice seems to be stable in the near-surface. The SS depth increases with larger grain size. Another words, ice becomes stable deeper. The model for average regolith provides SSD values around 80 meters in the equatorial region. Below the SSD (as well as poleward latitudes 40-45° in the near-surface) highly hydrated minerals (CaSO₄·2H₂O,



properties, average surface temperature, atmospheric water content and the geothermal gradient [7]. The aim of that work is to evaluate stability of hydrated minerals based on our model for temperature and water vapor partial pressure (P_{H₂O})

$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, and goethite) become stable. Above the SSD more desiccated hydrates becomes more stable toward the surface (see Fig. 2). Corresponding concentration of bound water could decrease from the depth up to the surface. The results show that bound water content could be relatively high in the ice-free desiccated regolith even in the equatorial region. Fine-grained regolith should provide higher near-surface bound water contents in comparison with coarse-grained regolith. Besides, fine materials should contain more salts as a fine products of chemical weathering. Water vapor exchange due to dehydration and hydration of minerals might contribute to planetary water balance and atmospheric evolution.

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Fig. 2. Stability of hydrates as a function of depth and latitude for fine-grain regolith model. Dashed lines show steady-state depths.

